REMARKS/ARGUMENTS

Claims 1, 4-8, 10-14, and 16-18 have been examined and finally rejected. The present response accompanies a Request for Continued Examination. The included remarks are believed to overcome all of the grounds of rejection. Reconsideration and allowance of all pending claims are respectfully requested.

Also, the Examiner is thanked for his courtesy in the telephone conference of December 10, 2003. The below arguments are a further development and refinement of the points raised by the undersigned in that conversation. One of the inventors, Ada Braverman, has performed extensive simulations that are highly useful in illustrating the advantages and differentiations of the claimed invention. The simulation results are found in an attached Appendix.

Claims 1, 4, 5, and 7 have been rejected under 35 U.S.C. 103(a) as being unpatentable over Pub. No. 2002/0021864 by Emori, et al., (hereinafter "Emori") in view of a publication by Namiki, et al., (hereinafter "Namiki") and further in view of U.S. Patent No. 6,292,288 issued to Akasaka, et al. (hereinafter "Akasaka"). Emori is cited as disclosing, e.g., groups of N and N+1 optical pump energy sources to induce Raman amplification. Namiki is cited as teaching selection of pump wavelengths to obtain a flat gain spectrum. Akasaka is cited as teaching alternating pump wavelengths between forward and backward directions.

No reference, however, has been shown to teach the limitations of claim 1 in an integrated system that achieves flat amplification response by virtue of the use of N pump wavelengths in a first direction, N+1 pump wavelengths in a second direction where the wavelengths alternate between the first group and the second group. It is respectfully submitted that it would not have been obvious to combine the teachings of the references cited against claim 1 for at least the reason that surprising results are obtained by the recited combination of features. These results will be further explained with reference to the Appendix.

The design of a Raman amplification system involves a complex set of tradeoffs. The Raman amplifier must provide sufficient gain to overcome losses along the span. Generally, the more gain that can be achieved, the greater the distance that can be achieved between optical amplification sites, directly affecting cost of the link. This gain should be achieved over a large bandwidth. The bandwidth of the amplifiers along a link determine how many channels can be carried, directly affecting link revenue.

The flatness of gain across the bandwidth is also a highly important figure of merit for Raman amplifiers. To satisfy receiver dynamic range requirements, it is necessary to have a flat gain response across the bandwidth. Flatness can be achieved by the use of gain flattening filters but these have an associated insertion loss that compromises the overall gain.

Achieving all of these objectives simultaneously is an enormous challenge. The designer can shift pump wavelengths and adjust pump powers to identify an optimal solution. However, improvements on one front often mean setbacks on another front. Reductions in gain variation across the band may be achieved only at the expense of overall gain. If pump power is increased arbitrarily in an effort to increase gain, there are undesired consequences such as nonlinear effects of gain saturation and four-wave-mixing between signal energy and pump energy. Other complications arise in that bandwidth and a desired amplification window should be maintained.

Referring now to the table on page 1 of the Appendix, simulation results are presented for five different configurations of pump wavelength and pump power. As in the example of given at the bottom of page 12 of the present application, a gain of 23 dB is desired to compensate for the loss of a fiber span and multiplexers. The configuration of column 1 is in accordance with the present invention and employs two counter-propagating pump wavelengths and three co-propagating pump wavelengths while the configurations of columns 2-5 use two pump wavelengths of each type. Gain and gain deviation versus wavelength are plotted in Figs. 1-10 of the Appendix.

It is apparent that configuration 1 achieves the desired 23.2 dB simultaneously with 1.2 dB of gain deviation using two co-propagating and three counter-propagating pumps. Configuration 2 represents an optimization of pump powers at the same four wavelengths to achieve the same gain flatness. As can be seen the 1.2 dB gain flatness can be achieved *but only at the expense of a 6.1 dB loss of gain*. This is a highly indicative point of comparison between embodiments of the present invention and the prior art that employs N co-propagating and N+1 counter-propagating wavelengths. The 6.1 dB difference in average gain is a very large disparity. In the context of a real-world optical communication system, this would correspond to a loss of hundreds of kilometers, e.g 1470 km instead of 2000 km, of available span length and a great increase in cost.

The remaining columns show configurations optimized to recover the lost gain by varying pump wavelengths and powers. Configuration 3 allows for optimization of pump wavelengths at the expense of shifting of the amplification window away from its target range. Only half the average gain is recovered but the gain deviation is doubled compared to what was achieved in configuration 1.

Configurations 4 and 5 increase the pump powers of the configuration of column 3 to recover the remaining lost gain. Configuration 5 exhibits 2.0 dB of gain deviation. There is however, a limit to the use of pump power increases to increase gain since undesired non-linear effects such as saturation and four-wave-mixing begin to appear.

The combination of gain and gain flatness provided by embodiments of the present invention represents a surprising result that defeats any contention that the references relied upon by the Examiner would have been obvious to combine. The multiple objectives of gain, gain flatness, and bandwidth are achieved by relying on the recited features of claim 1 including the use of N pumps in one pumping direction and N+1 pumps in the other pumping direction where the pump wavelengths alternate between directions.

Because the references would not have been obvious to combine, the rejection of claim 1 is overcome. Claim 1 is therefore allowable over the art of record. Claims 4, 5, and 7 are allowable for at least the reason of their dependence from claim 1.

Claims 8, 10-14, and 16-18 have been rejected under 35 U.S.C. §103(a) as being obvious over Akasaka in view of Emori. As a threshold matter, independent claims 8 and 14 recite that pump wavelengths are selected to flatten amplification response. This feature is neither disclosed nor suggested by the Akasaka and Emori references. This deficiency is sufficient to defeat the rejection.

Furthermore, it would not be obvious to combine the Akasaka and Emori teachings for the same reasons discussed in reference to claims 1, 4, 5, and 7. Favorable and unexpected results are obtained by embodiments of the present invention as indicated by the simulations presented in the Appendix. This is further reason for the allowability of independent claims 8 and 14. Claims 10-13 and 16-18 are allowable for at least the reason of their dependence from allowable claims 8 and 14.

Conclusion

For the foregoing reasons, Applicant believes all the pending claims are in condition for allowance and should be passed to issue. If the Examiner feels that a telephone conference would in any way expedite the prosecution of the application, please do not hesitate to call the undersigned at (408) 446-8694.

Respectfully submitted,

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Simulation Results

Configuration number	1		2		3		4		5	
Pump configuration	2+3		2+2		2+2		2+2		2+2	
Total gain dev.	1.2		1.2		2.4		2.4		2.0	
Min wavelength (nm)	1572		1572		1579.6		1579.6		1578.2	
Max wavelength (nm)	1617		1617		1624.6		1624.6		1623.2	
Bandwidth (nm)	45		45		45		45		45	
Average Gain (dB)	23.2		17.1		20.3		23.3		23	
Pump wavelength (nm) and power (mW)	1455(ctp)	120	1455(ctp)	-	-	-	-	-	-	-
	1472(ctp)	145	1472(ctp)	100	1470	145	1470	220	1470	230
	1509(ctp)	160	1509(ctp)	100	1513	160	1513	205	1513	195
	1463(cop)	215	1463(cop)	200	1459	215	1459	225	1459	235
	1499(cop)	225	1499(cop)	200	1501	225	1501	215	1501	205

APPENDIX

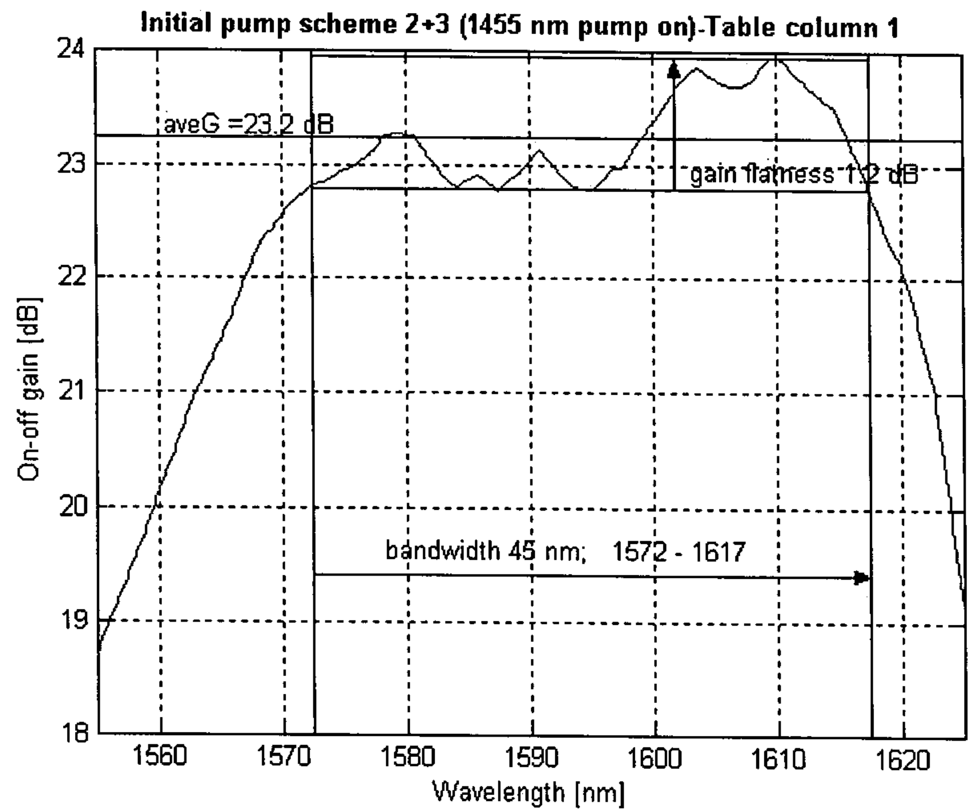

Fig. 1. On-off gain corresponding to the 2+3 pump scheme (column 1)

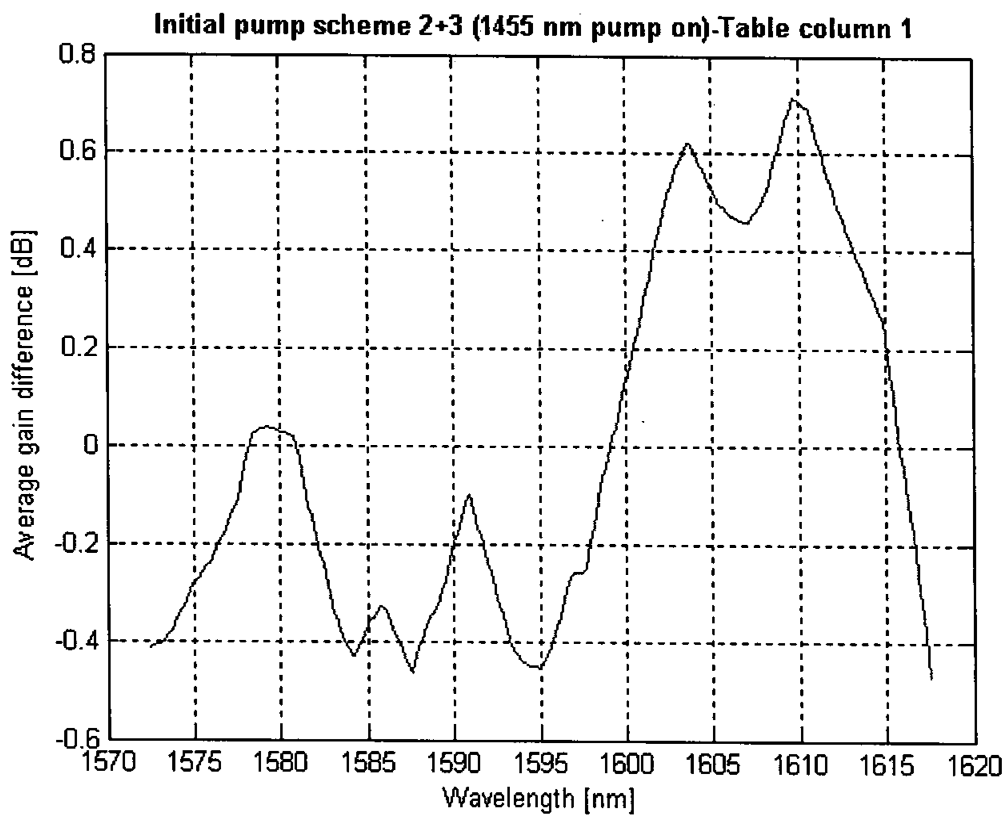

Fig. 2. Average gain deviation corresponding to the 2+3 pump scheme (column 1)

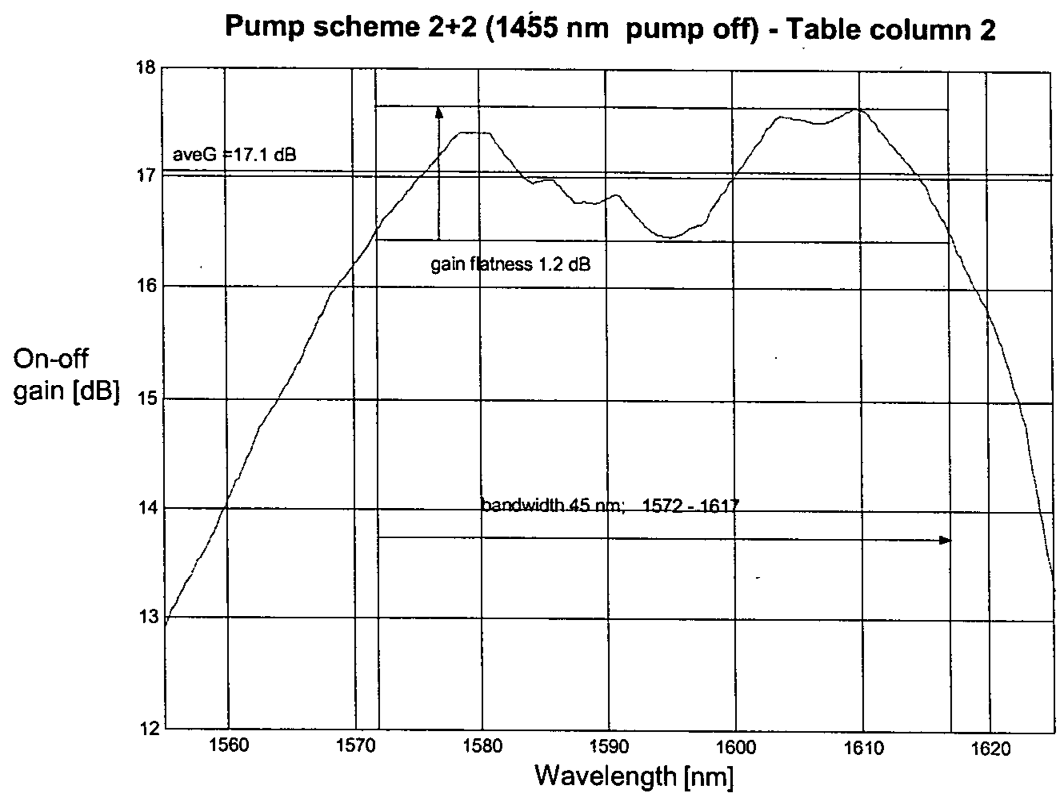

Fig. 3. On-off gain corresponding to the 2+2 pump scheme (column 2)

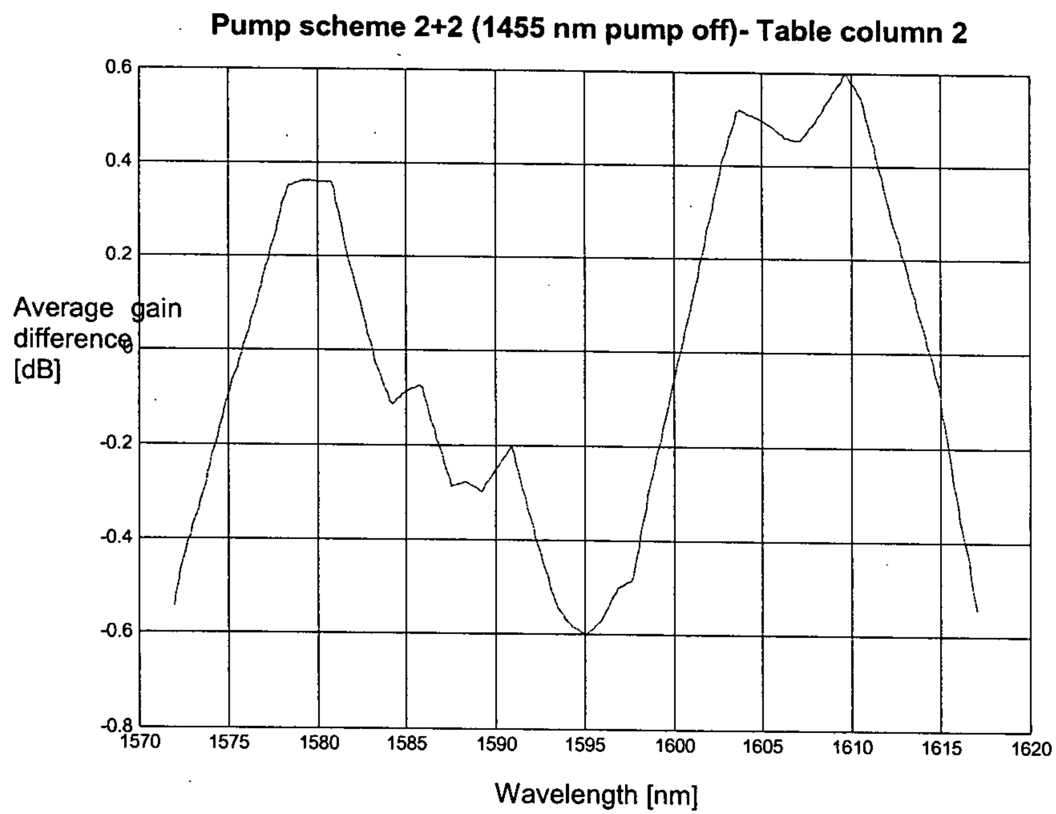

Fig. 4. Average gain deviation corresponding to the 2+2 pump scheme (column 2)

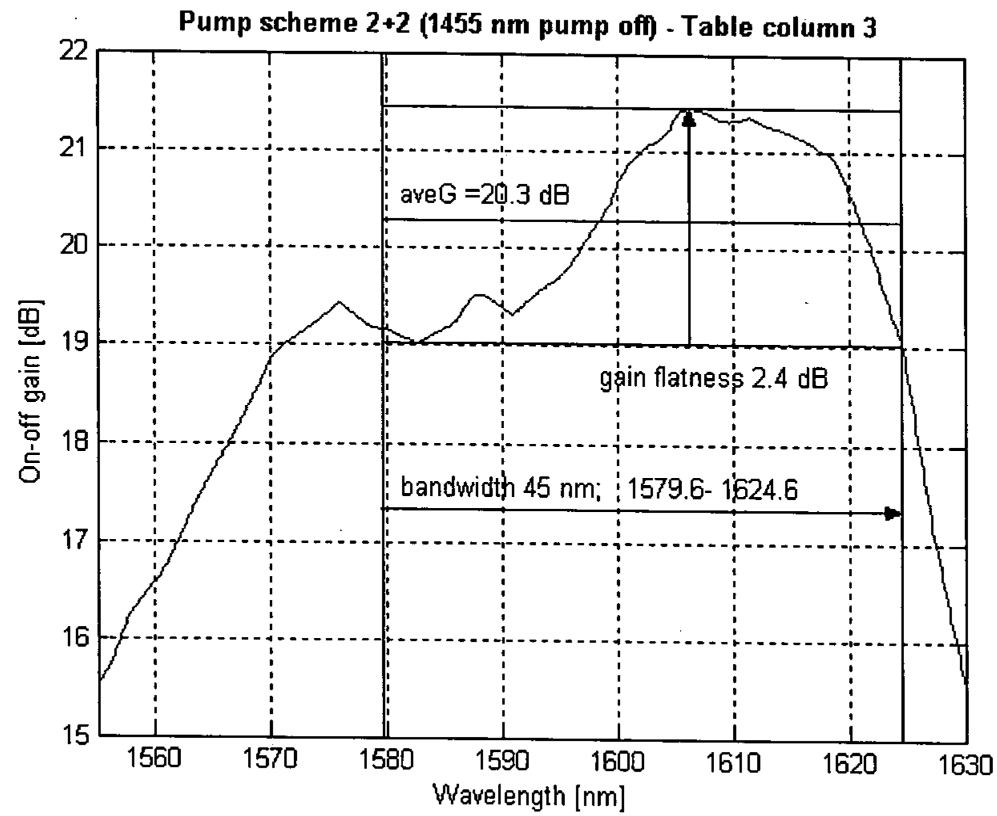

Fig. 5. On-off gain corresponding to the 2+2 pump scheme (column 3)

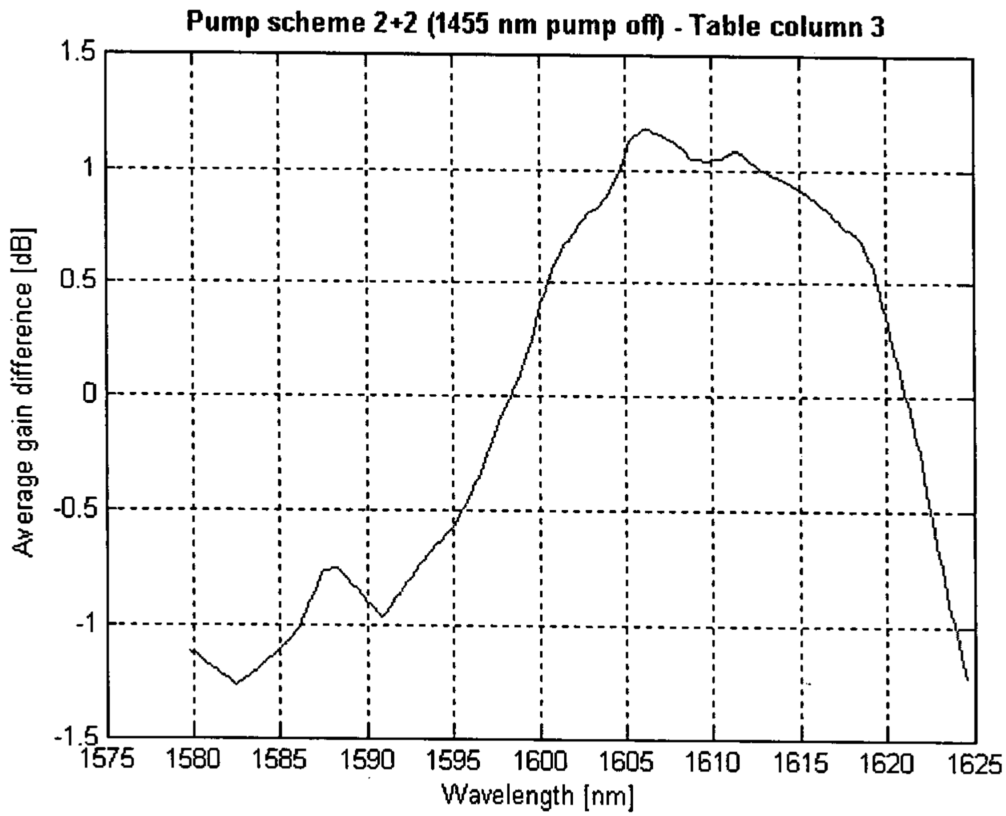

Fig. 6. Average gain deviation corresponding to the 2+2 pump scheme (column 3)

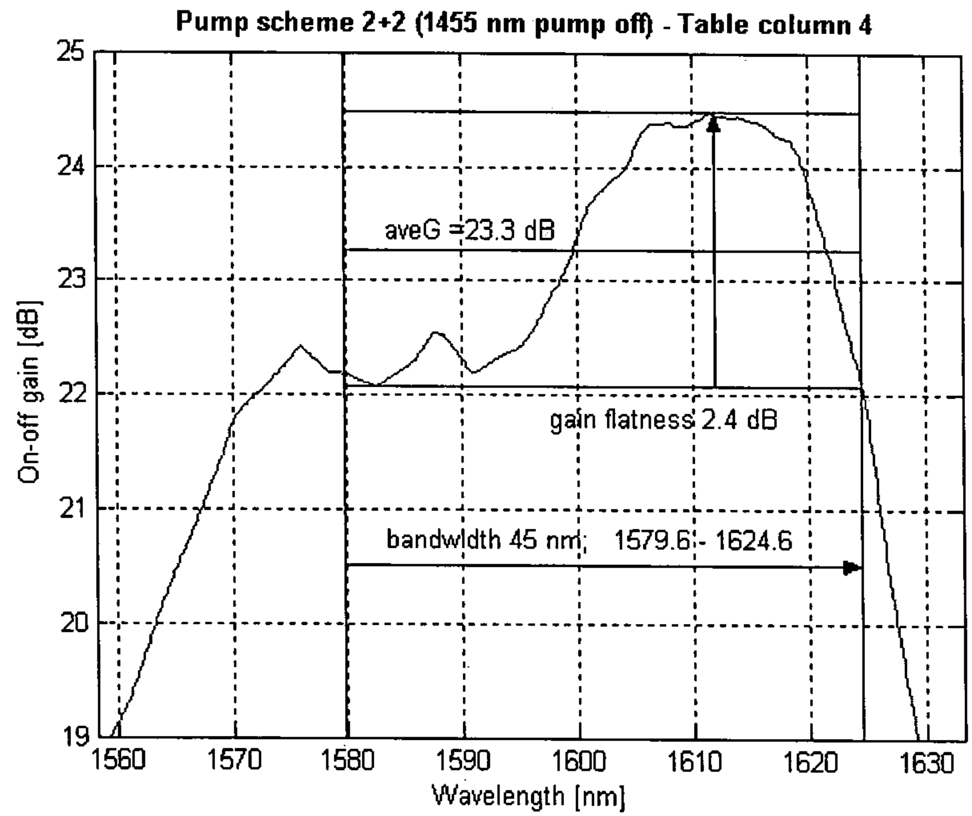

Fig.7. On-off gain corresponding to the 2+2 pump scheme (column 4)

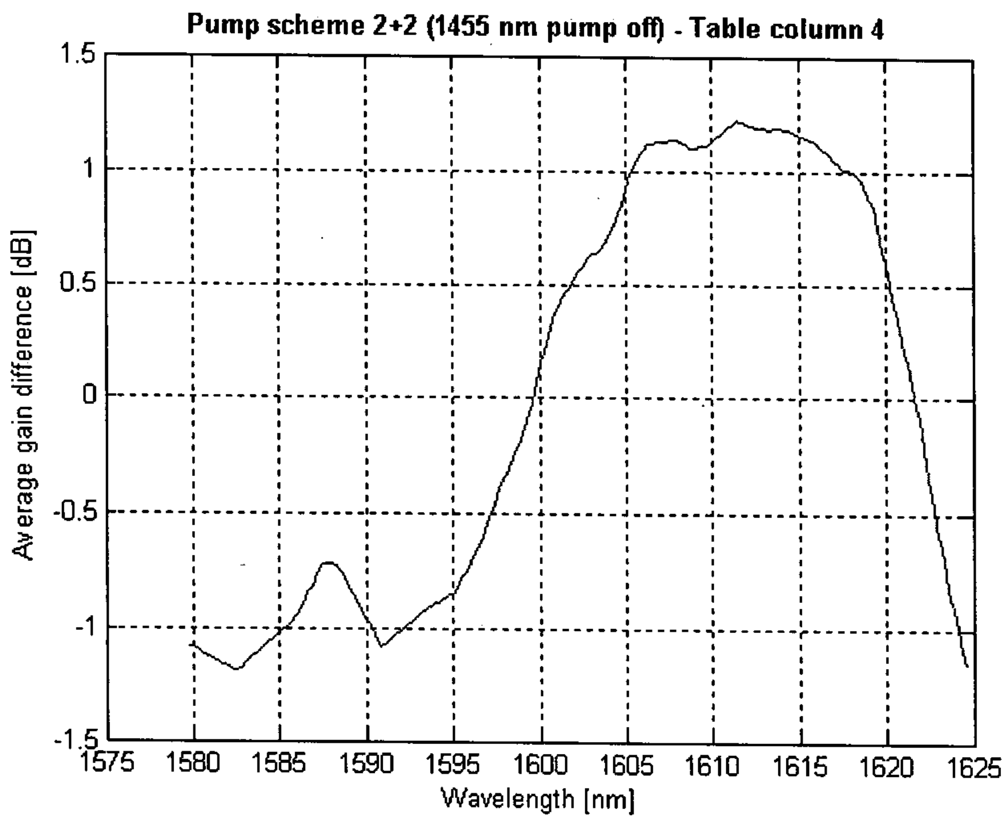

Fig. 8. Average gain deviation corresponding to the 2+2 pump scheme (column 4)

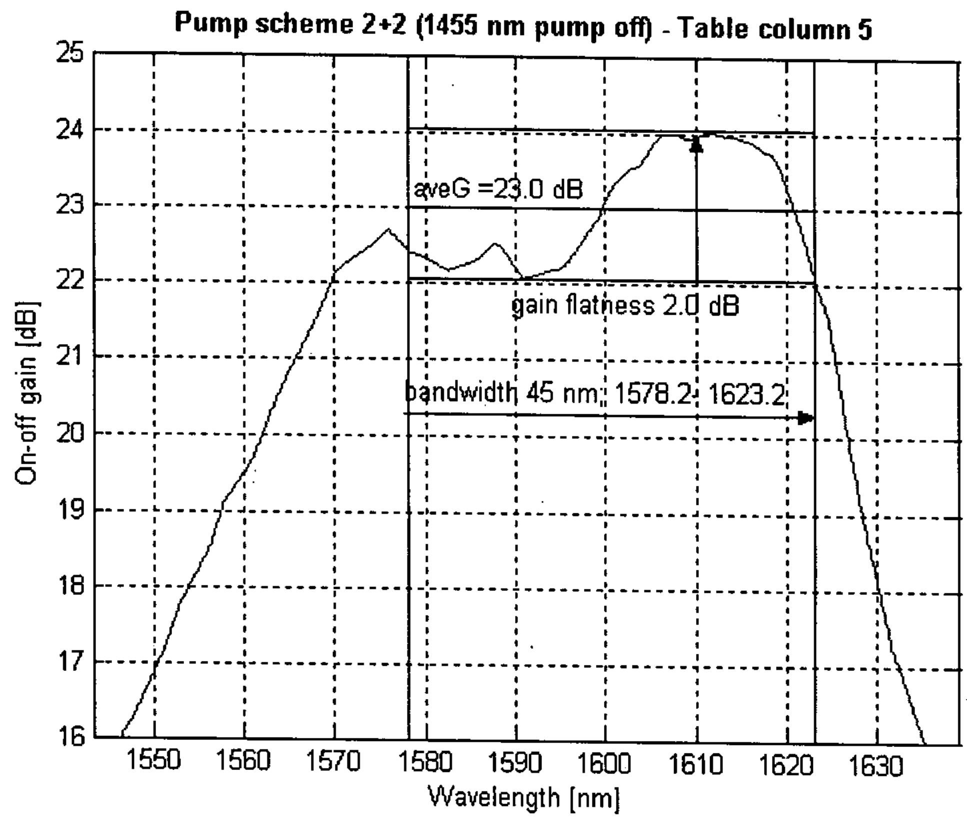

Fig.9. On-off gain corresponding to the 2+2 pump scheme (column 5)

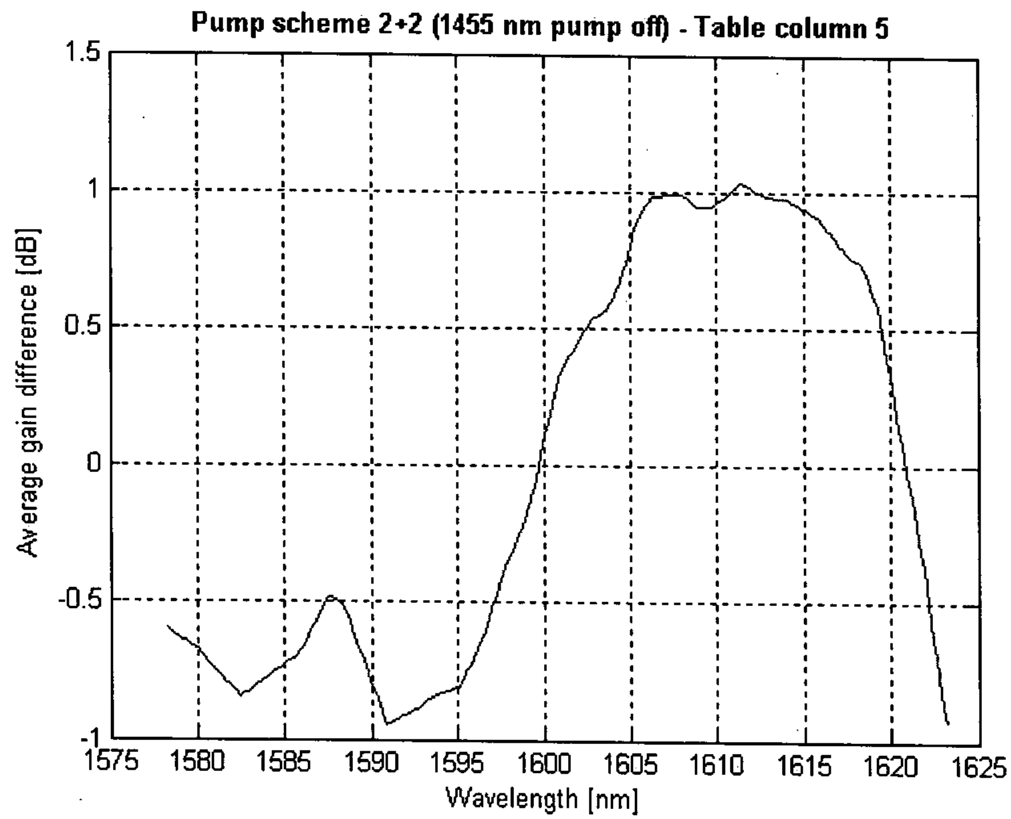

Fig. 10. Average gain deviation corresponding to the 2+2 pump scheme (column 5)